Optimizing Building Energy Use:
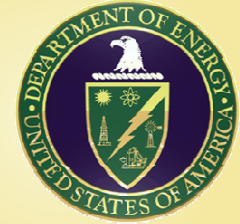## A Systemic Approach

by

Chris Marnay & Michael Stadler

This file contains just the SEDS part of the talk given in Washington D.C. on Oct. 28th 2008.

The entire presentation can be found at http://der.lbl.gov

Optimizing Building Energy Use:
A Systemic Approach

by

Chris Marnay & Michael Stadler

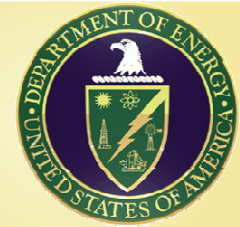*C_Marnay@lbl.gov* & *MStadler@lbl.gov* - *+1.510.486.7028* - *http://der.lbl.gov*

other team members: Hirohisa Aki, Inês Lima Azevedo, Sam Borgeson, Brian Coffey, Ryoichi Komiyama, Kristina LaCommare, Judy Lai, & Afzal Siddiqui

28 Oct 2008

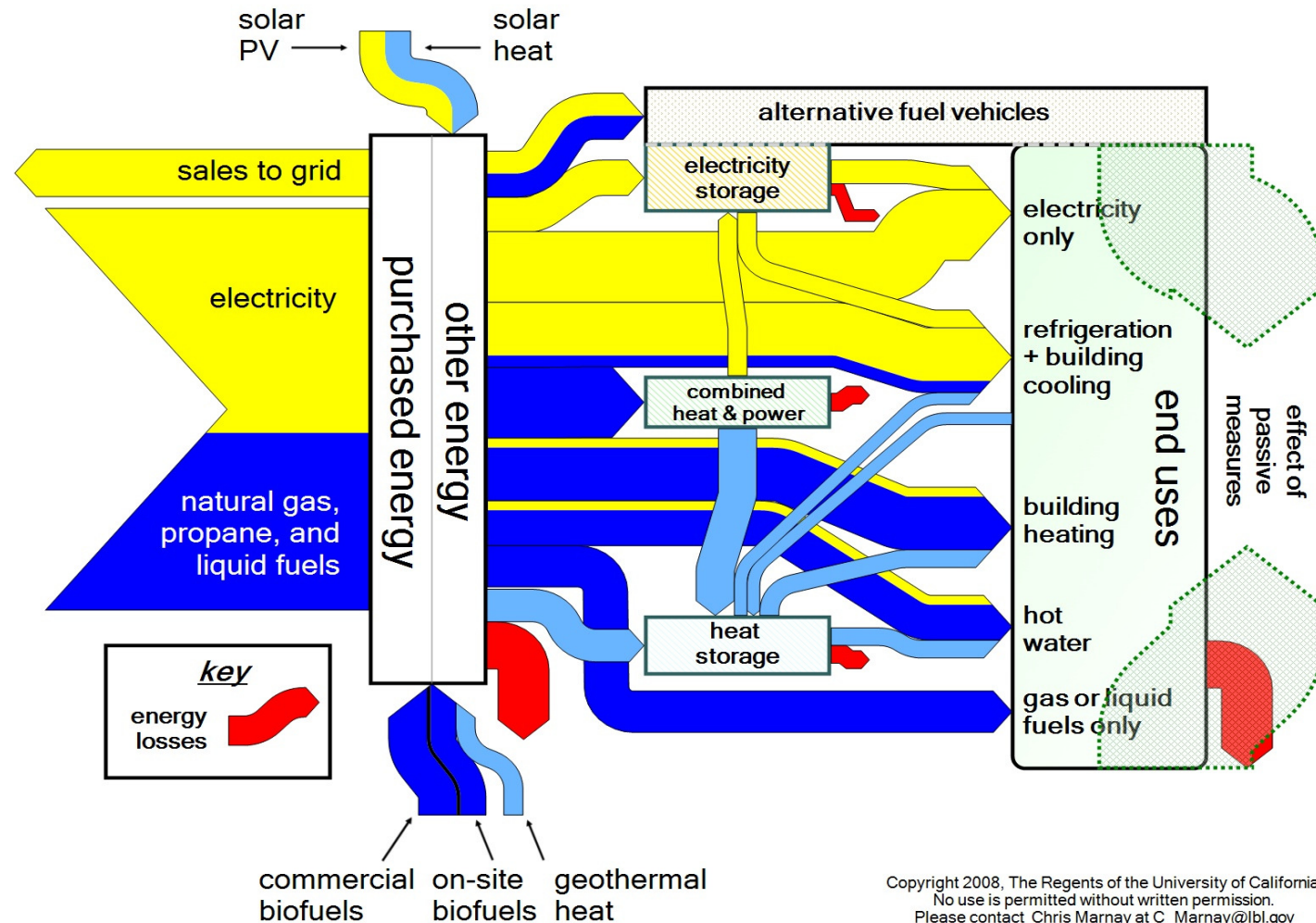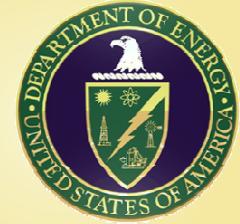## U.S. Dept. of Energy, Washington DC

Outline

- systemic analysis of building energy systems

- executive summary

- Distributed Energy Resources Customer Adoption Model (DER-CAM)

- Stochastic Energy Deployment System (SEDS)
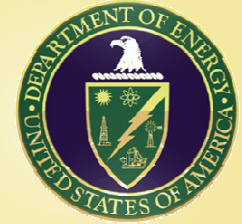
- conclusions and future work

Exec. Summary

systemic approach applied in two distinct models:

Distributed Energy Resources Customer Adoption Model
- given hourly end-use requirements, DER-CAM produces pure technology neutral optimal results and schedules
- can find optimal installation & use of storage
- reveals cost-carbon abatement trade-off curve and optimal ZNEB solutions
- requires extension into demand-side, financials, etc.

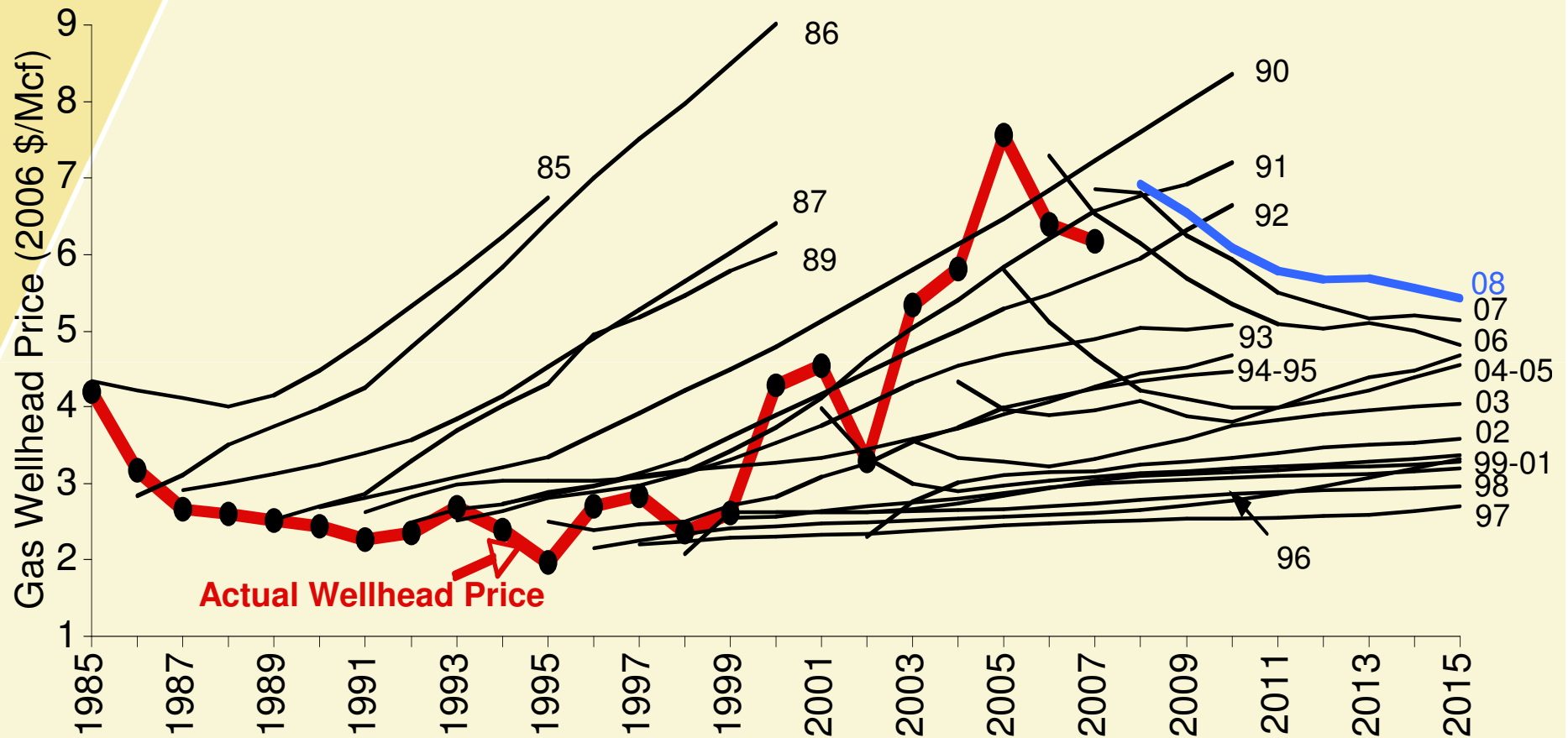Stochastic Energy Deployment System
- Berkeley Lab has built the SEDS Lite Buildings Module
- and can conduct rudimentary analyses of PV and SSL

Stochastic Energy Deployment System (SEDS)

SEDS Objectives

build US energy forecasting model with:

- uncertainty, vision, simplicity, & transparency,
    - > uncertainty: build model on Analytica® platform
    - > vision: 2050 horizon, dramatic tech. & taste change
    - > simplicity: no equilibria or optimization (no iteration,)
    - > transparency: open source, consistent module format

- extremes of policy and outcomes needed

- enough prepackaged technical & budget detail

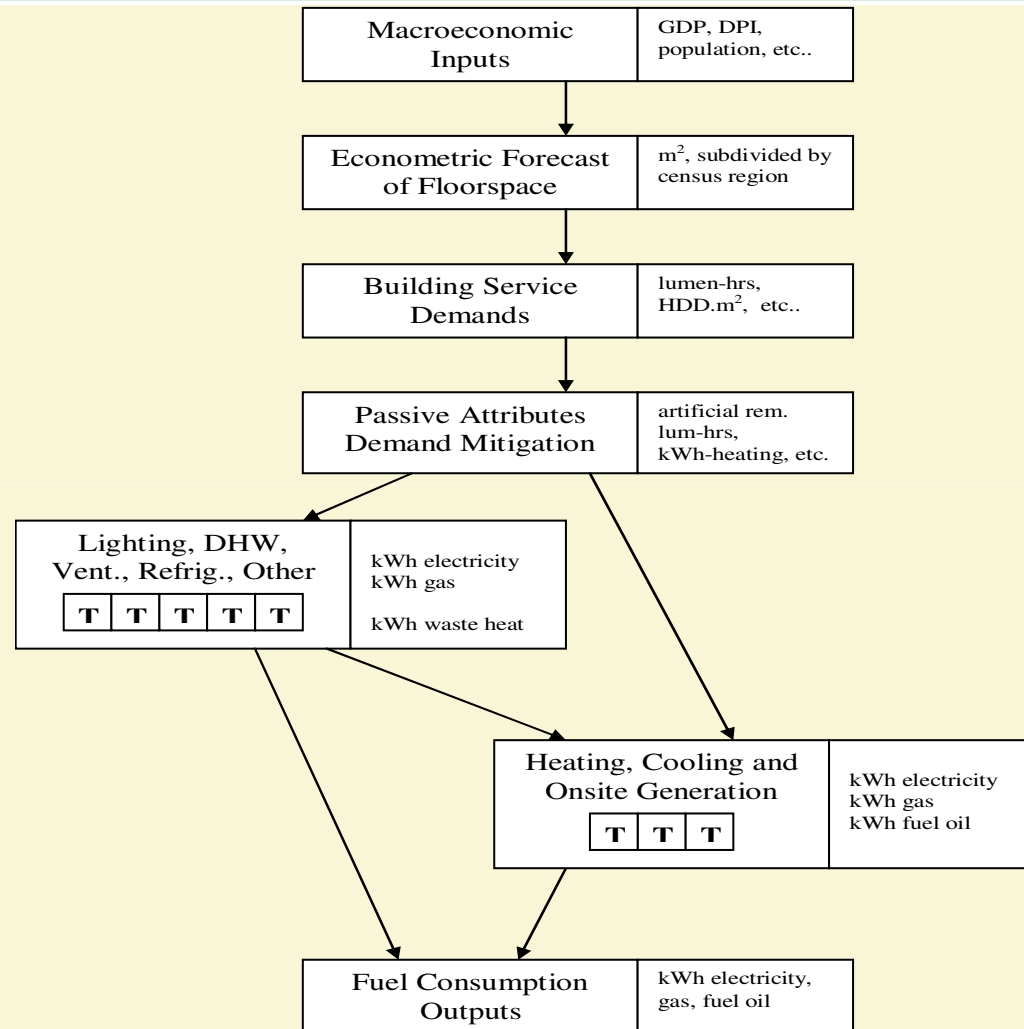- ability to run in minutes

Buildings Lite Module
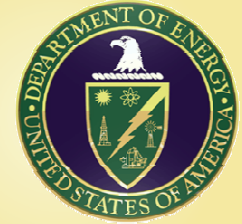
Berkeley Lab responsible for the buildings sector:

- covers both residential and commercial

- tracks building stock

- enables analysis of major buildings R&D programs

- uses expert elicitation of potential advances

- runs stand-alone or integrated

- applies systemic approach

Macroeconomic Inputs	GDP, DPI, population, etc..

Econometric Forecast of Floorspace	m^2, subdivided by census region

Building Service Demands	lumen-hrs, $HDD.m^2$, etc..

Passive Attributes Demand Mitigation	artificial rem. lum-hrs, kWh-heating, etc.

Lighting, DHW, Vent., Refrig., Other T T T T T	kWh electricity kWh gas kWh waste heat

Heating, Cooling and Onsite Generation T T T	kWh electricity kWh gas kWh fuel oil

Fuel Consumption Outputs	kWh electricity, gas, fuel oil

Two Program Examples

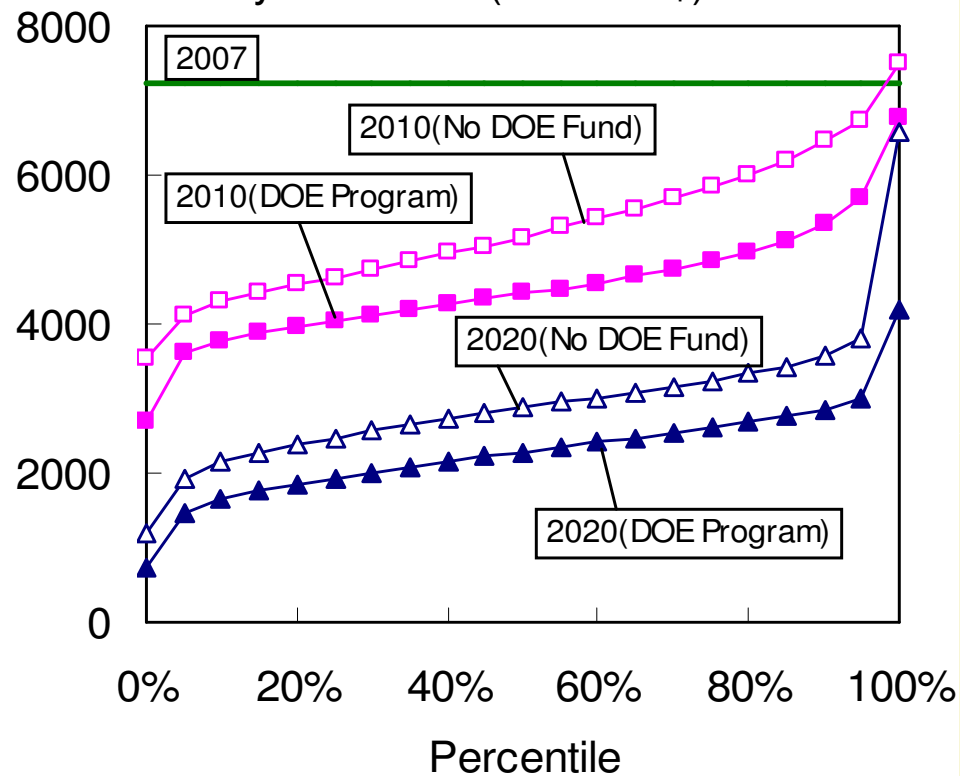**first cut photovoltaic and solid state lighting examples:**

- uses stand-alone SEDS Buildings Lite Module (SBLM)
  for a ~30-draw Monte Carlo analysis

- takes stochastic inputs for GDP, energy prices,
  & population

- applies PV/SSL performance forecast based
  on expert assessment

- implements expert elicitation of potential advances

- employs the systemic approach

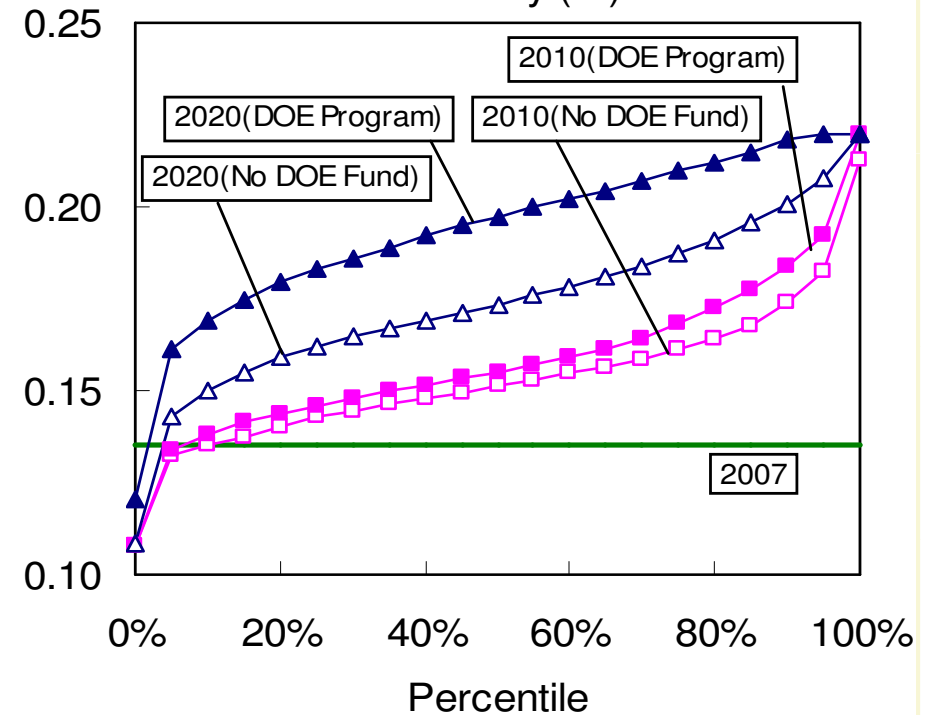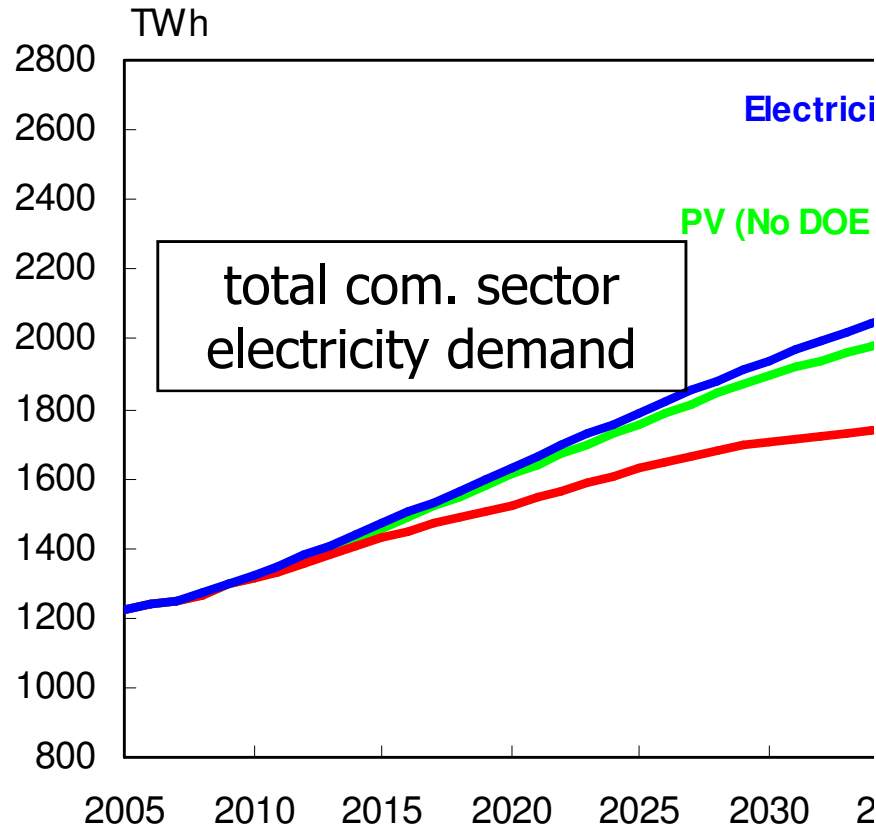# Expert Forecasts

PV System Cost (2005 US$)

2007
2010(No DOE Fund)
2010(DOE Program)
2020(No DOE Fund)
2020(DOE Program)

Percentile

Conversion Efficiency (%)

2010(DOE Program)
2020(DOE Program)
2010(No DOE Fund)
2020(No DOE Fund)
2007

Percentile

Effect on Demand

total com. sector electricity demand

Electrici

PV (No DOE

TWh

total 2050 buildings electricity from PV
without DOE program: 11.7%
with DOE program: 26.1%

com. + res. PV generation

95th percentile

50th percentile

5th percentile

TWh
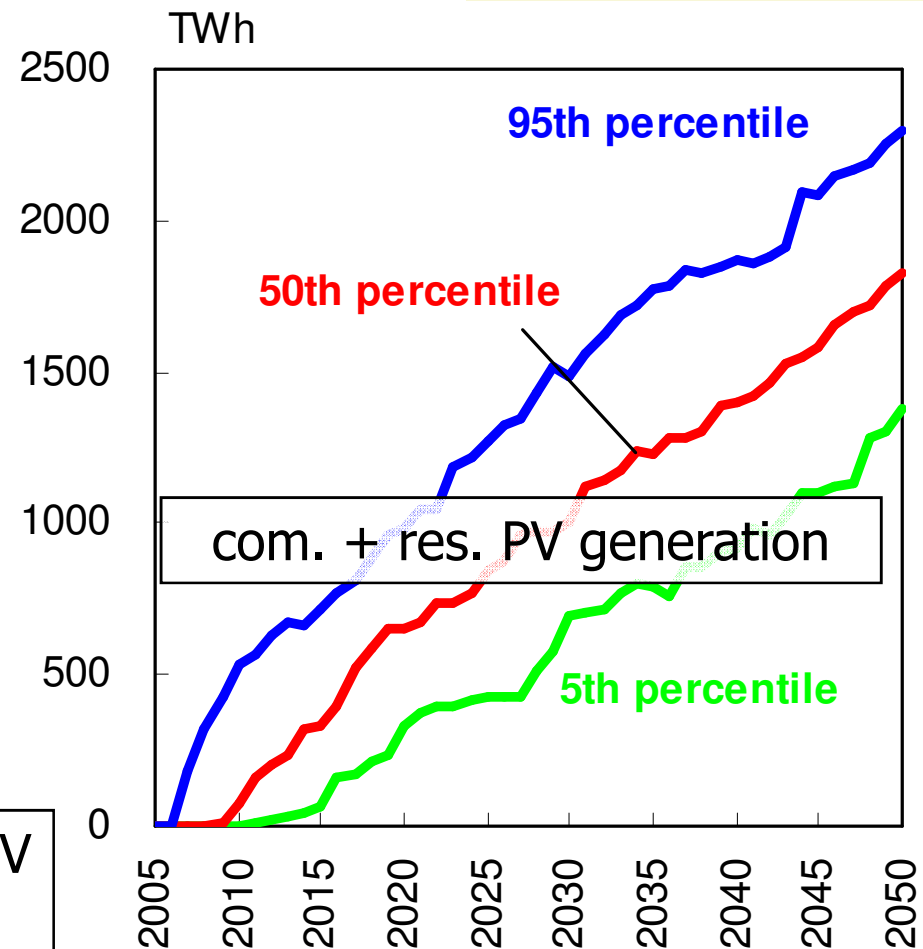
Role of Logit Alpha

$$MS_{i,t} = \frac{v_{i,t}}{\sum_{i} v_{i,t}}$$

$$v_{i,t} = \exp(-\alpha * LCOE_{i,t})$$

MS = Market share
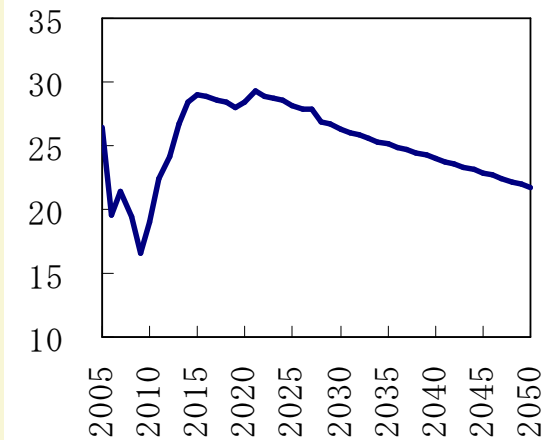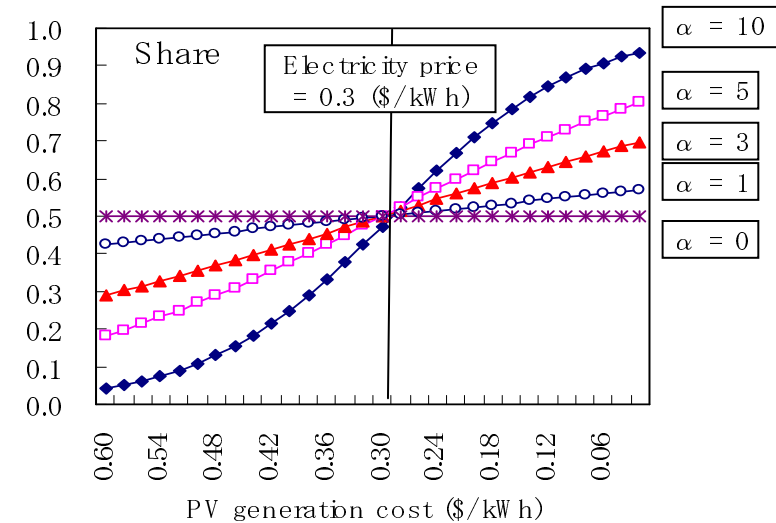*LCOE* = levelized cost of energy (>0)
υ = utility
α = scaling factor
i = technology types
   $i \in$ {utility electricity, PV gen.}
t = time

$$\alpha = A + B * electricity\ price$$

S.S. Lighting Example

$/klumen

percentile

SSL Efficacy

DOE's 2015 projection for luminaire efficacy (with funding)

DOE's 2012 projection for luminaire efficacy (with funding)

DOE's 2010 projection for LED luminaire efficacy

DOE's 2007 estimate for LED luminaire efficacy

2020 with DOE funding

2020 no DOE funding
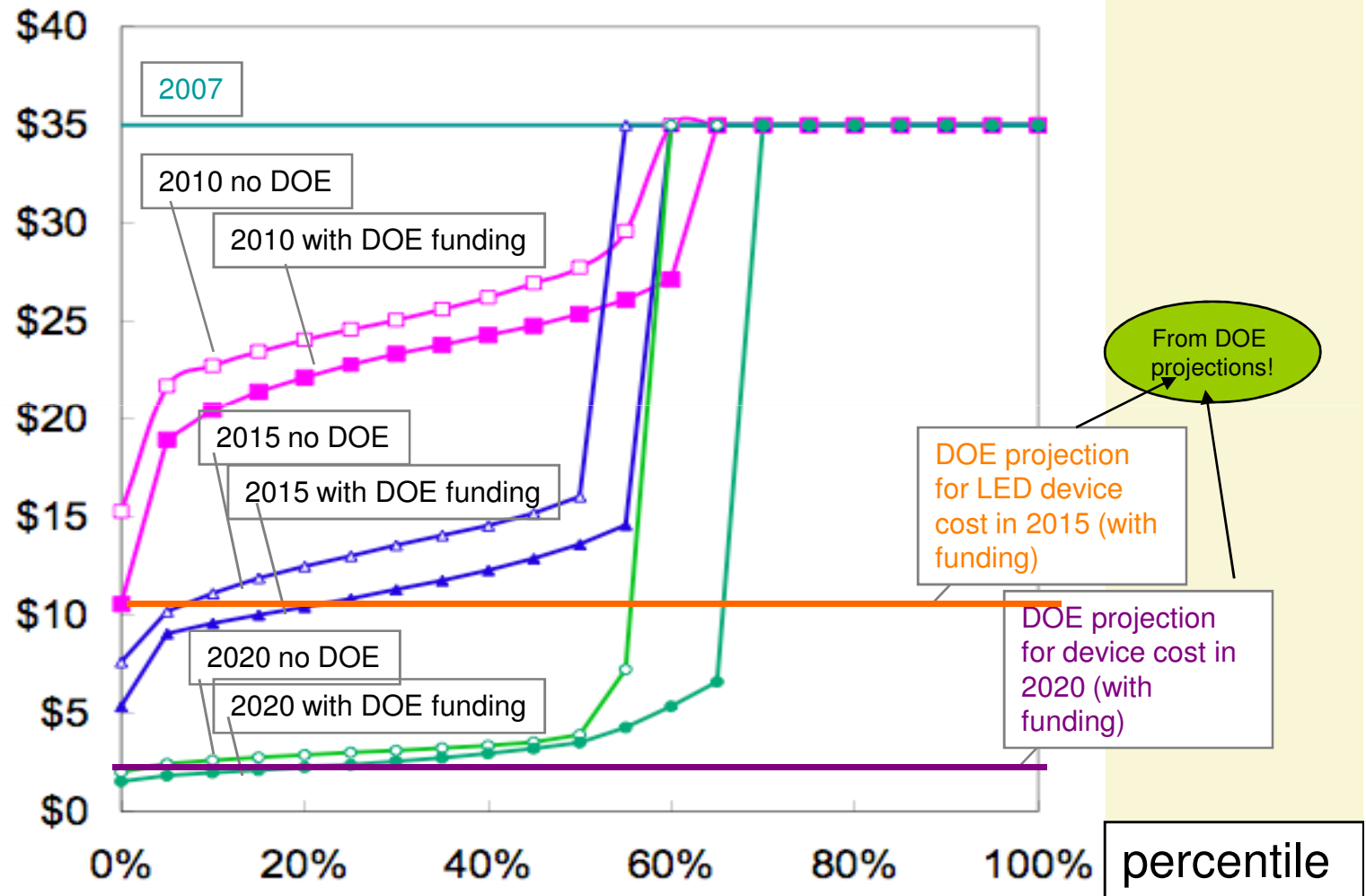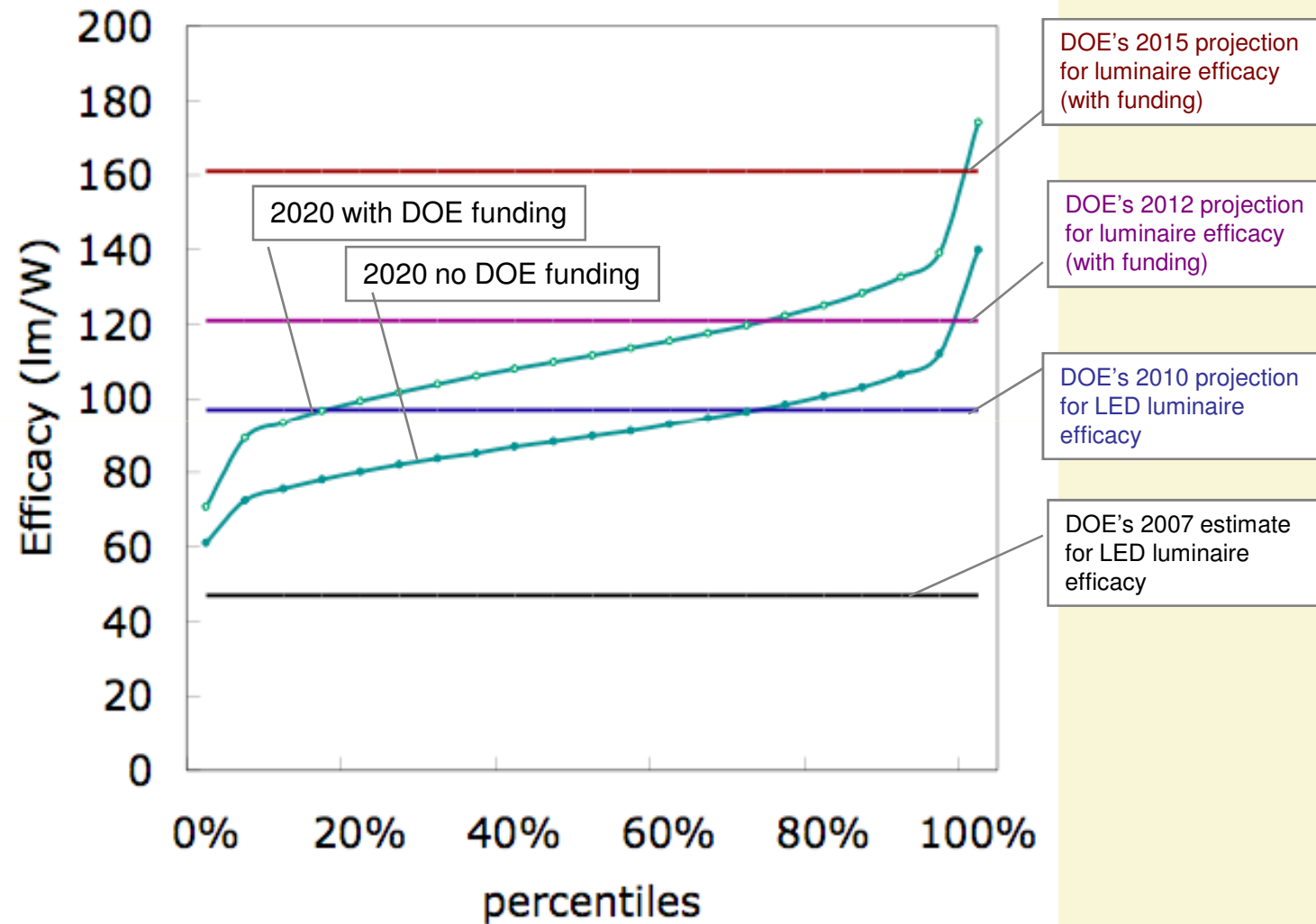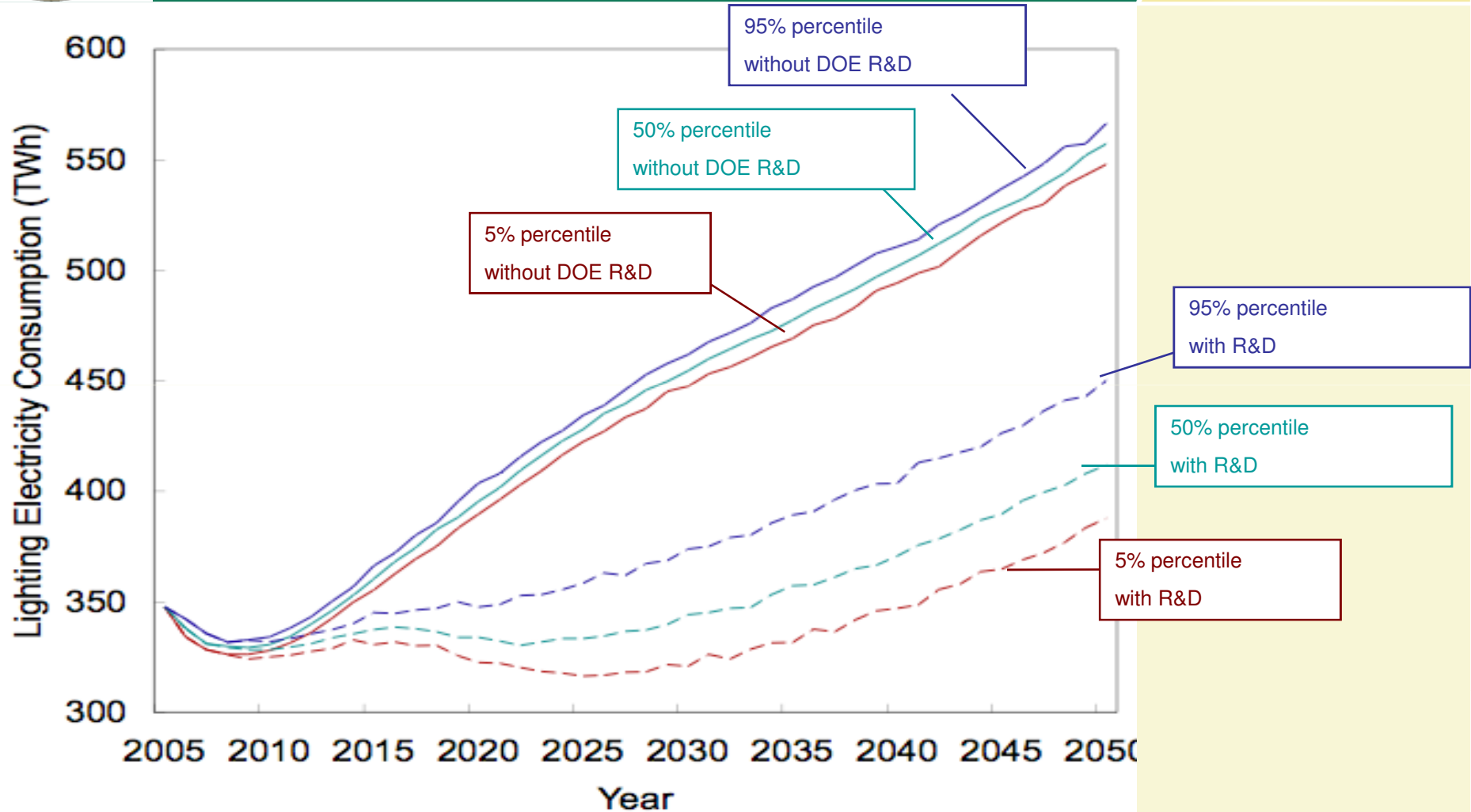
Lighting Consumption

DER-CAM+SBLM Pubs.

Firestone, Ryan, and Chris Marnay. "Distributed Generation Dispatch Optimization under Various Electricity Tariffs," the E-Business Applications in the Energy Sector special issue of the *International Journal of Electronic Business Management*, vol. 5(3), Sep 2007.

Hatziargyriou, Nikos, Hiroshi Asano, Reza Iravani, and Chris Marnay. "Microgrids*," IEEE Power and Energy* magazine, vol 5(4), Jul-Aug 2007.

Marnay, Chris, and Ryan Firestone. "Microgrids: An Emerging Paradigm for Meeting Building Electricity and Heat Requirements Efficiently and with Appropriate Energy Quality," Proceedings of the *European Council for an Energy Efficient Economy Summer Study Summer Study 2007*, La Colle sur Loup, France, 4-9 June 2007.

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Marnay, Chris, Michael Stadler, Sam Borgeson, Brian Coffey, Ryoichi Komiyama, and Judy Lai. "A Buildings Module for the Stochastic Energy Deployment System," Proceedings of the *ACEEE 2008 Summer Study on Energy Efficiency in Buildings*, August 17 – 22, 2008.

Marnay, Chris, Giri Venkataramanan, Michael Stadler, Afzal Siddiqui, Ryan Firestone, and Bala Chandran. "Optimal Technology Selection and Operation of Microgrids in Commercial Buildings," *IEEE Transactions on Power Systems*, 10.1109/TPWRS.2008.922654, vol. 23(3), Aug 2008.

Marnay, Chris. "Microgrids and Heterogeneous Power Quality and Reliability: Matching the Quality of Delivered Electricity to End-Use Requirements," International Journal of Distributed Energy Resources, vol 4(4), Oct-Dec 2008.

Siddiqui, Afzal, and Chris Marnay. "Operation of Distributed Generation Under Stochastic Prices," *Pacific Journal of Optimization*, vol. 3(3), Sep 2007.

Siddiqui, Afzal, Chris Marnay, Ryan Firestone, and Nan Zhou. "Distributed Generation with Heat Recovery and Storage," *Journal of Energy Engineering* special issue on Distributed Generation, vol. 133(3), Sep 2007 .

Siddiqui, Afzal S and Chris Marnay, "Distributed Generation Investment by a Microgrid under Uncertainty," *Energy,* forthcoming.

Siddiqui, Afzal S and Karl M Maribu, "Investment and Upgrade in Distributed Generation under Uncertainty," *Energy Economics*, forthcoming.

Stadler, Michael, Hirohisa Aki, Ryan Firestone, Judy Lai, Chris Marnay, and Afzal Siddiqui. "Distributed Energy Resources On-Site Optimization for Commercial Buildings with Electric and Thermal Storage Technologies," paper to be presented at the *2008 ACEEE Summer Study on Energy Efficiency in Buildings*, August 17–22, 2008.

Stadler, Michael, Chris Marnay, Afzal Siddiqui, Judy Lai, Brian Coffey, and Hirohisa Aki. *The Effects of Storage Technologies on Microgrid Viability: An Investigation for Commercial Buildings in California and New York States*," draft report, Oct 2008.
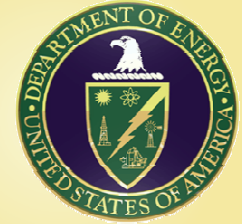
Venkataramanan, Giri, and Chris Marnay. "A Larger Role for Microgrids," *IEEE Power and Energy* magazine special issue on microgrids, vol 6(3), May-Jun 2008.

(all papers available at: http://eetd.lbl.gov/ea/emp/ or1 http://der.lbl.gov)

Future Work

systemic approach applied in two distinct models:

- 🟢 Distributed Energy Resources Customer Adoption Model
- ⦿ ready for prime time? rewrite, distribution, …
- ⦿ passive and demand-side measures, better boxes
- ⦿ forecasting, financials, uncertainty, thermodynamics, mobile sources,
- ⦿ open source data base of tariffs, equip. perform., etc.
- ⦿ advanced financial methods, options, sequencing, …
- ⦿ related studies: ZNEB (less silly), V2M, standard blgs.,

- 🟢 Stochastic Energy Deployment System
- ⦿ extend to heavy Module (regions), …, integration, etc.
- ⦿ windows, & ..

Thank you!